Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 173 (2017) 1499 – 1506
Procedia Engineering
www.elsevier.com/locate/procedia

11th International Symposium on Plasticity and Impact Mechanics, Implast 2016

Simulated Design of a Flow Control Valve for Stroke Speed Adjustment of Hydraulic Power of Robotic Lifting Device

A. O. M. Adeoye [a], A. A. Aderoba[a], B. I. Oladapo [a]*

[a]*Department of Mechanical and Mechatronics, Engineering, Afe Babalola University, Ado-Ekiti, Nigeria*

Abstract

A novel method of design for a hydraulic robotic lifting equipment (HRLE) was modelled, commonly used by marinas and Automobile industries. Lifting appliances have different working principles because of their individual characteristic behaviours. This work analysis a characteristic curve made from values obtained from various adjustments of the stroke working speed of the hydraulic lift system and the time used. A hydraulic lift of an experimental setup was developed for different adjustable heights and speeds and simulated to get the actual optimum value of operation under different loading conditions. The motion was free of inconsistent movement and a steady speed was attained after a 0.6s maximum time limit. A flow control valve and a pressure relief valve were used to adjust the speed without any extreme irregular high pressure. A demonstration for possibilities and applicability of HRLE is presented which is applicable both in industries and institutions for learning.

Peer-review under responsibility of the organizing committee of Implast 2016

Keywords: Robotic lifting system; Characteristic curve; Simulation; Speed; Height Adjustment; Flow control valve;

1.0. Introduction

It is of great importance in this modern time that the commercial airline, marina seaport, and vehicle industry have an assisting crew [1]. In the waiting hour on the ship, airplane and automobile components, the crew is busy loading and off-loading cargos and load with the use of different lifting equipment [2]. The refueling of ship tanks and aircrafts for the preparation of next departure is determine by the loading of the tanks and the cargo. All these activities must be

* Corresponding author. Tel.: +2348032503054;
*E-mail address:*bioladapo@abuad.edu.ng

Peer-review under responsibility of the organizing committee of Implast 2016
doi:10.1016/j.proeng.2016.12.230

carefully handled to ensure maximum safety and complete loading and off-loading in the stations. Therefore, the operation of different lifting equipment are required, in spite of the safety problem. Unsafe operations of lifting equipment had brought about many casualties in the marine, aircraft, and vehicle industries. Research has shown that 19% of accidents of over 339 deaths of workers from 1992 till date were from lifting equipment [1, 3]. Further studies on safety and precaution show that the majority of damage and fall from a height of 3m-10m is 59%. 33% of every 35 deaths of critical accidents are related to the vehicle mounting elevation, these were due to failure of lifting equipment [3-5]. The design model, simulation and experimental validation of assisting robotic lifting system for the industry is very vital. It also helps to generate device for lifting of equipment. Reduction in vibration and apparent weight of the object prevents frequent occurrence of the accidents [5, 6]. Therefore, the vertical controlling forces that are required to lift an object with the use of hydraulic robotic lifting equipment will be lower than the force required to lift an object manually [7]. This research designs and analyses the hydraulic system of hydraulic robotic lifting equipment with the objective of improving the characteristic curve pressure of hydraulic system for robotic lift. The experimental design of the system was validated in Festo workstation [7, 8].

Nomenclature

F	Gravitational force [N]
x	Piston displacement [m]
M_p	Piston mass [kg]
B_p	Effective bulk modulus
A_p	Piston area [m^2]

The objective is to design a hydraulic model robotic lifting device in FluidSIM® software which has optimum safety requirements for industrial lifting equipment. Analysis of the characteristic curve of the force velocities and the pressures involved in lifting an object and give an optimum precision. The hydraulic was also simulated to lift the HRLE design to a specific height, reduce vibrations and give an optimum usage of pressure by using flow control valves. It also gave an experimental validation on the model design [9]. The model design process or flow diagram simulation and experimental set up of this hydraulic power robotic lifting equipment is given in Fig. 1, with several steps of actuation.

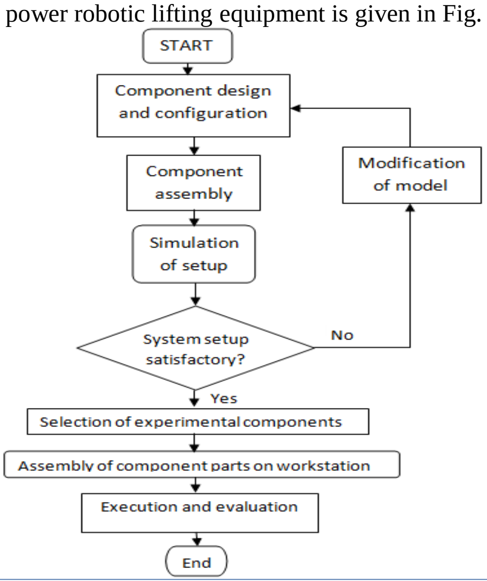


Fig. 1. Flowchart diagram of the designed simulation process.

The hydraulic power robots lifting equipment are also available for other good purposes like the lifting of baby carriages, lifting of automotive equipment, controlling system in bicycles, heavy door lifting systems, lifting of equipment in the manufacturing industries and for assisting agricultural workers in their day to day activities [10, 11]. The result presented by [7-10] were extensively extended with more advanced control techniques and semi-automatic control principles that improved power robot lifting devices. Also, one of the major new ideal in this research is the method of optimizing the pressure usage by introducing a well developed and configured flow control valve to adjust the movement of the flow of the fluid within the system both for the forward and backward strokes. The objective of work was to estimate the relationships between actual and perceived weights, velocities and lengths of stroke for lifting objects with little or no power-assist. The objective of experiment was to validate the relationships and confirm the reliability of the simulated values. Estimation methods of weight perception between the simulation and experiments were slightly different. However, the results were accurate enough to satisfy the objectives of the experiments.

2. **The principle of hydraulic power of a robotic lifting equipment.**

2.1 Model design and configuration

The set up of hydraulic power robotic lifting equipment was designed, configured and simulated by the FluidSIM® software as shown in Fig. 2. The model is used to regulate the speed and vibration. A two-way flow control valve and pressure relief valve were used to regulate the height and reduce the vibrating effect of the system [12, 13]. The design is simple and easy to understand for easy application or incorporation into any hydraulic lifting machine. Its movement is of high agility, heavy load carrying capacity, a steady movement and conventional operating system.

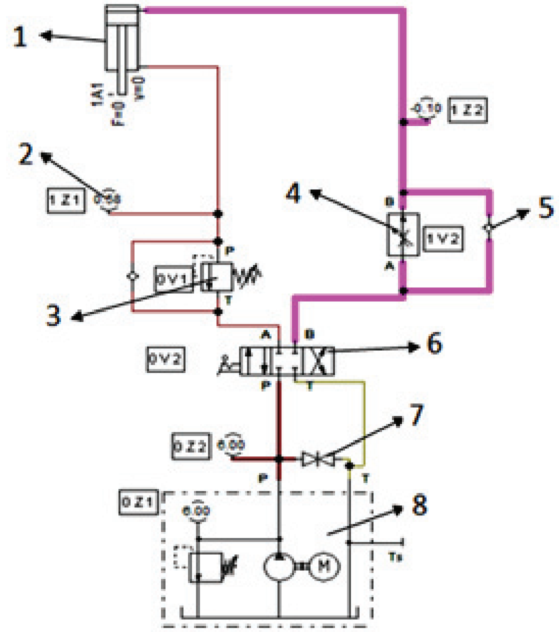


Fig. 2. A configured setup of the hydraulic power robotic lift showing the fluid flow after simulation.

From Fig. 2 the description of the components of the hydraulic lift robot simulation on the software are represented by: 1-Double acting cylinder, 2-Pressure gauge (Manometer), 3-Pressure relief valve, 4-Two-way flow control valve, 5-Check valve, 6- 4/3-way hand-lever valve in a shutoff position, 7- One-way shutoff valve, 8-Hydraulic pump. Table 1. describe the component part of the HRLE system, the quantities of each of the component used and the designations for each of the component according to the International Numbering Standard for hydraulic component for FluidSIM® system.

Table 1 Part description for both the simulated and experimental model.

Designation	Quantity	Description of Part
1V3	1	2-way flow control valve
1V1	1	4/3-way hand-lever valve with shutoff position
	2	Check valve
1A1	1	Double acting cylinder
0Z2, 1Z1, 1Z2	3	Manometer (pressure gauge)
0V1, 0V4	2	Pressure relief valve
0Z1	1	Pump unit
0V2	1	Shutoff valve

6	Loading weight
6	Hose line
1	Stopwatch

2.2. Cylinder Model for movement of the hydraulic power robotic lifting equipment.

The objective of the mathematical cylindrical model is to express an equation that gives resultant cylindrical force, which can give the non-potential force of the hydraulic power robotic lifting device. Precisely the resultant force acting on the double-acting cylinder is the product of the differential pressure across the sectional area of the cylinder, which also support Newton's second law of motion according to the following equation:

$$M_p=F_1-F_2+F_g-F_{fr} \quad (1)$$

$$M_p + B_p - A_p - P_L = 0 \quad (2)$$

The dynamic equations of the nonlinear flow control valve and the double-acting cylinder actuator are represented by the equations. This is the governing equation for the force of the HRLE for both the simulation and the experimental value. Where; *F is* Gravitational force, *x is* Piston displacement, M_p is Piston mass, is Effective bulk modulus, and A_p is Piston area of the cylinder, these are all the parameters of the equations

3. Control and description of hydraulic power robotic device

The main component of the robotic lift platform is the weight of the system which is about 20 kg. The working distance which is the length of the double acting cylinder strokes of 200mm with a piston area of 201.0 mm^2 of a maximum moving velocity of 0.123 m/s.

To control the hydraulic lifting robot, it is necessary to adjust the height of the system and then lock it up after determining the location of standing. This is done by using 2-way flow control valve in combination with a check valve to close the inlet of the oil and the return check valve. To adjust the height, it requires a precise positioning of the shutoff in the supplying element and regulating the pressure valve in the supplying element. The vertical transportation device is similar to the operation of hydraulic lift compare to the lifting process in many hydraulic systems, which usually make use of elements consisting of electricity, oil pump, pressure gauge, balance valve, hose pipe, hydraulic cylinder safety valves and some other hydraulic component. All these make up the set-up for this hydraulic power robotic device.

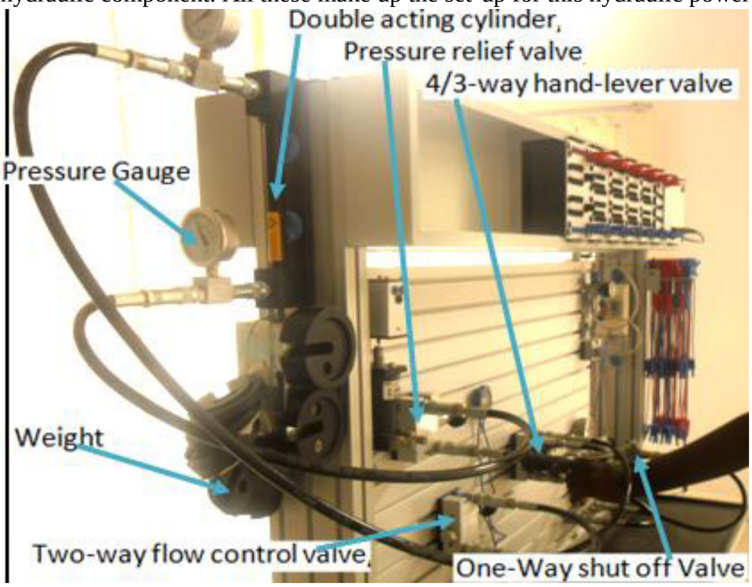
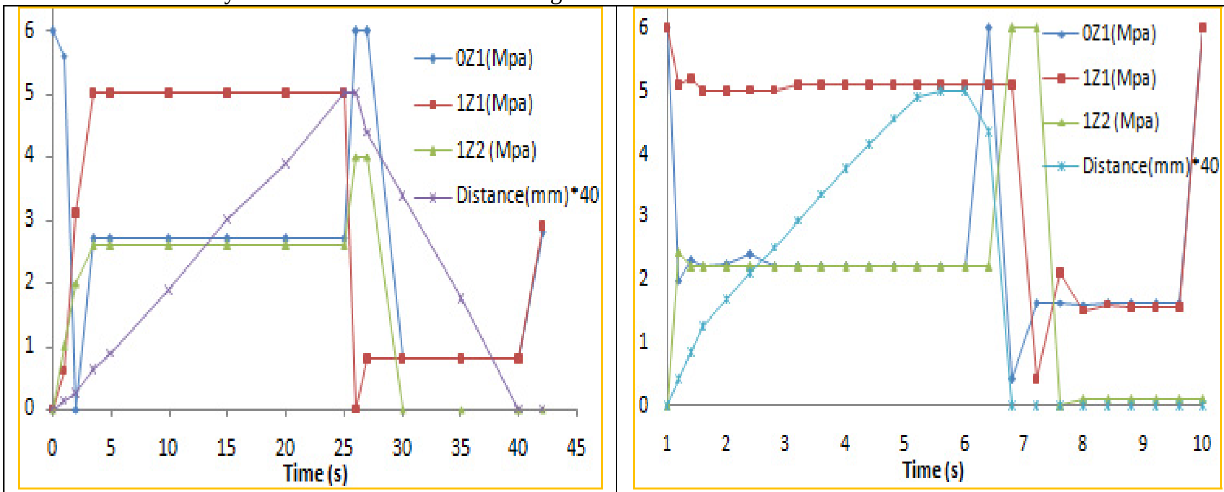


Figure 3 Experimental set-up of HRLE

This set-up was operated under regular electricity supply. Electrical energy was converted to energy in hydraulic pressure form with the motor hydraulic pump, which helps in actuating the system. The ascending and descending effective speed and movement was controlled by the use of 4/3-way control valve. The overloading security setting should always be set in any hydraulic system **[13]**. The pressure relief valve should not be greater than 100% of working condition on the model FluidSIM® software and the experimental workstation should not be greater than 110%of working condition. The pressure of the pressure relief valve was adjusted before lifting operation on both systems and restricted to the maximum allowable working conditions as described vividly in Fig. 3.

4. **Results and discussion**

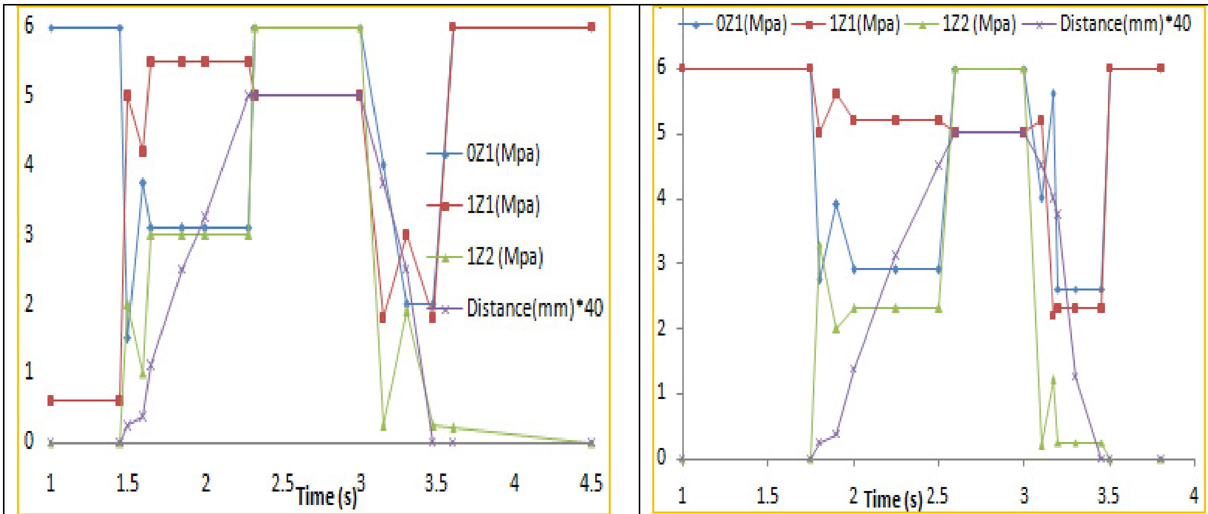
The maximum working force of the loading system for the hydraulic power robotic system is 180N. After the maximum loading, there was a prolong vibration in the system according to Figs. 4 and 5. This was also confirmed in the experimental and simulation validation in Figs. 5 and 6. The movement, speed and vibration of the system were monitored and analyzed under three different working conditions.



A: 0.1 litre/min flow rate of the pressure relief valve for 90N loading.

B: 0.5 litre/min flow rate of the pressure relief valve of 180N loading.

Fig. 4. Distance, velocity and pressure against time for HRLE.

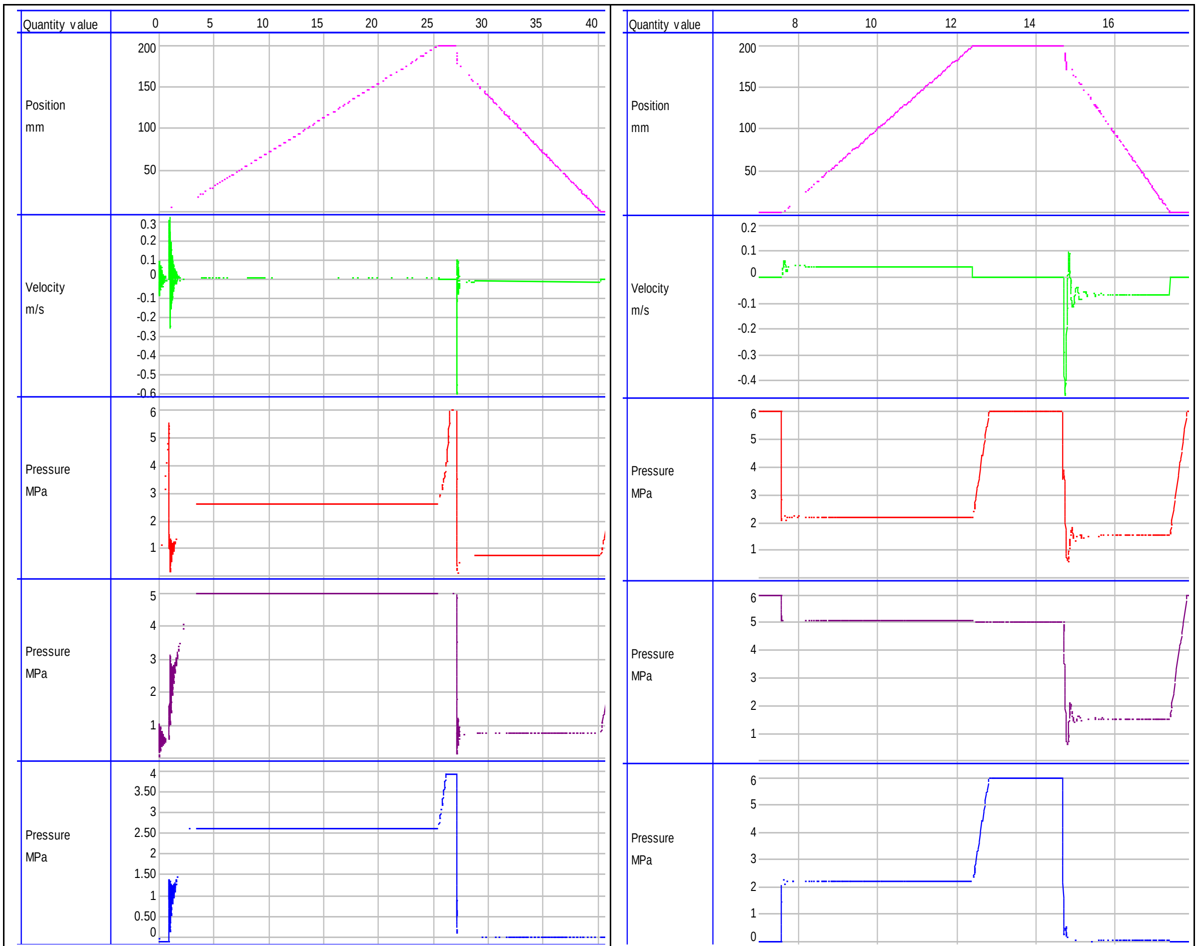


A: 3.0 litre/min flow rate of the pressure relief valve of 90N loading,

3.0 litre/min flow rate of the pressure relief valve of 180N loading.

Fig. 5. Distance, velocity and pressure against time for HRLE.

There was a vibration at the initial actuation of the system within the space of 0.5s. The system has then attained a stable position of a gradual increase in the distance and continued under regular pressure and constant speed. When the 4/3-way valve was actuated to the right direction of the cross flow system, there was a lifting of the robotic lift. This is shown in figure 7. The result of the simulation shows that between 0s to 2s there was a continuous vibration for 90N loading condition while for 180N shows a vibration for about 5s.

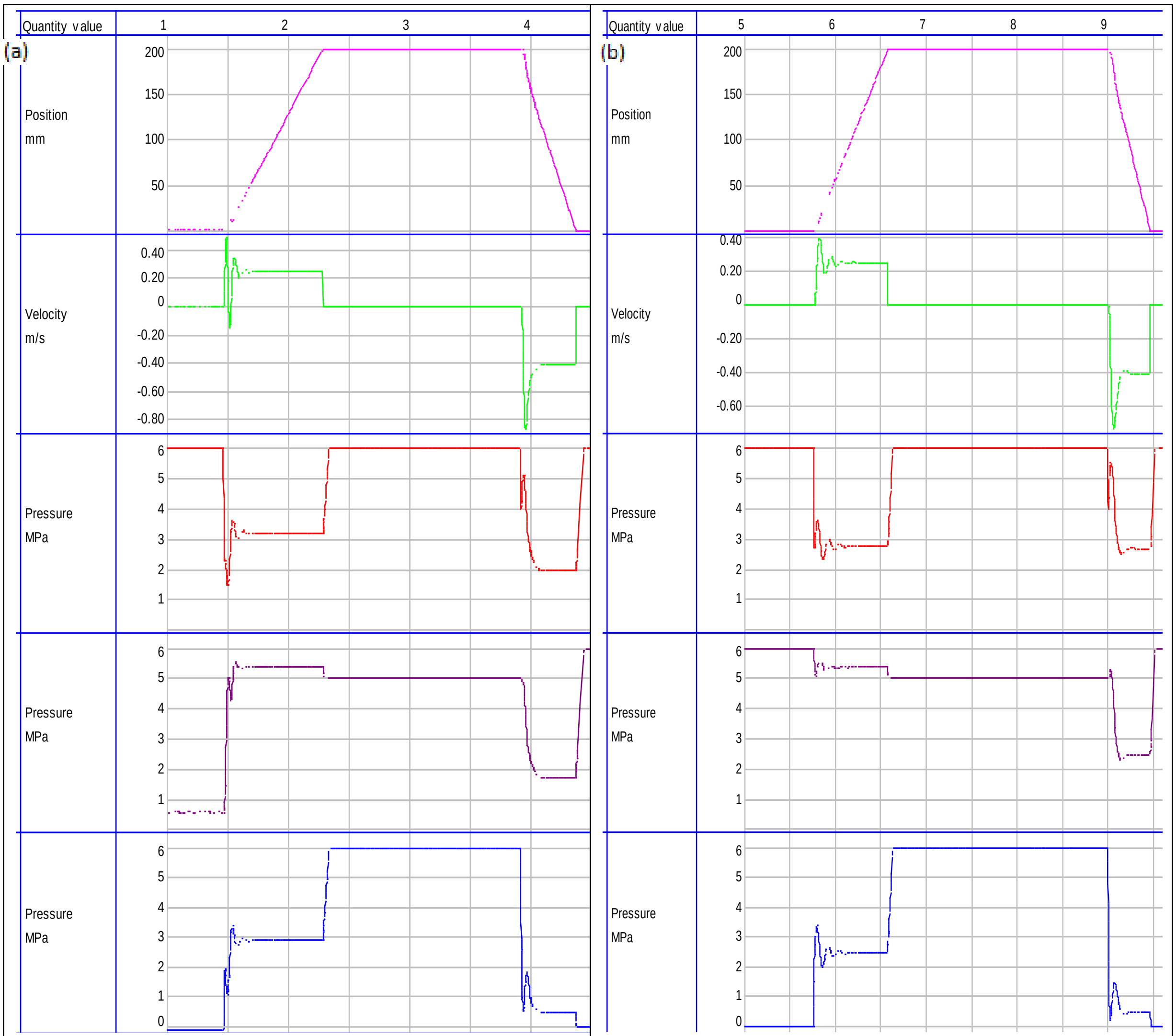


A: 0.1 litre/min flow rate of the pressure relief valve of 90N loading

B: 0.5 litre/min flow rate of the pressure relief valve of 180N loading

Fig. 6. Simulated result of the distance and different actuating pressures of the valves against time for HRLE.

In the upward movement of the HRLE, the result demonstrates a total time of 27s for the distance of 200mm lifting when the pressure relief valve is open until 0.1l/min flow rate. The manometer at the 0Z2 read about 2.5Mpa. This occurs for both the minimum and maximum loading condition. After increasing the flow rate to 0.5l/min, there was a faster movement of about 6.5s of the weight, both for the maximum and minimum loading. When the flow rate of the pressure relief valve was increased dramatically to 3.0l/min. The system covers the 200mm distance in about 2s. The pressure relief valve was used to adjust the speed of the HRLE. When the shutoff valve was open to 100%, the downward movement was two times faster for all the flow rate and working loading condition due to the gravitational force acting on the weight both on the simulated and experimental analysis.



A: 3.0 litre/min flow rate of the pressure relief valve of 90N loading condition

B: 3.0l/min flow rate of the pressure relief valve of 180N loading.

Figure 7 Simulated result of the distance and different actuating pressures of the valves against time for HRLE

5. Conclusions and recommendations

In this critical examination, the safety of the lifting device was considered, the HRLE platform was a model designed and analyzed both experimentally and in software simulation. These were finished through FluidSIM® software, hydraulic control system, different hydraulic valves and actuators.

1. The set-up test verified the stability, coordination and regulation of pressure flow in an HRLE system.
2. This will meet the needs of the automatic lifting device in the marina, aircraft and automobile industries and institutions of learning.
3. Without any human effort to support, holding can be advanced by lifting a weight of up to 180N and remain stable without vibration or failure using a well developed and configured valve.
4. It is recommended that this device be implemented for ergonomic bed and chair in the medical field
5. A steady speed is attained, adjusted and maintained during the operation with the use of pressure relief valves and a magnetic cushion introduced to both ends of hydraulic cylinder system for effective damping effect.

6. The breaking and characteristic hydraulic systems with different loading condition were achieved in a hydraulic power robotic lift that provides an improved platform for future research work and improvement.

References

[1] H. Rashid, M. Khairol, A. M. Ariffin, M. Hafiz, M. Noh, A. H. Abdullah, A. Hussein, A. Hamid, M. Azzeim, M. Jusoh, A. Othman. Design Review of Scissors Lifts Structure for Commercial Aircraft Ground Support Equipment using Finite Element Analysis. *Procedia Engineering 41 (2012) 1696 – 1701*.

[2] H. Cao, X. Chen, Y. Zi, F. Ding, H. Chen, J. Tan, Z. Hea, End milling tool breakage detection using lifting scheme and Mahalanobis distance. International Journal of Machine Tools and Manufacture. Volume 48, Issue 2, February 2008, Pages 141–151.

[3] S. Christopher, A.H. Pan, M. McCann, M. Lin, K. Fearn, P. Keane. Aerial lift fall injuries: A surveillance and evaluation approach for targeting prevention activities. Journal of Safety Research. 2007.

[4] H. Lei1,Y. Genfu, C. Xuehui, Simulation Analysis of Certain Hydraulic Lifting Appliance under Different Working Conditions. 2012 International Conference on Solid State Devices and Materials Science, Physics Procedia 25 (2012) 2268 – 2275.

[5] S. Zhao, J. Wang, L. Wang, C. Hua, Y. He. Iterative learning control of electro-hydraulic proportional feeding system in slotting machine for metal bar cropping. International Journal of Machine Tools and Manufacture. Volume 45, Issues 7–8, 2005, Pages 923–931.

[6] B. I. Oladapo, V. A. Balogun, S. O. Oyegoke, A. O. M. Adeoye, C.O. Ijagbemi , S.O. Afolabi, I. A. Daniyan, S. O. Akinola, A. P. Simeon, I. D. Uchegbu. Experimental analytical design of CNC machine tool SCFC based on electro-pneumatic system simulation, Eng. Sci. Tech., Int. J. 19 (2016) 1958–1965

[7] Y. Altintaş, A. J. Lane. Design of an electro-hydraulic CNC press brake. International Journal of Machine Tools and Manufacture, Volume 37, Issue 1, January 1997, Pages 45–59.

[8] G. Liu, Y. Yan, J. Chen, T. Na, “Simulation and experimental validation study on the drive performance of a new hydraulic power assist system,” *in Proc. of 2009 IEEE Intelligent Vehicles Symposium*, June 3-5, 2009, pp.966-970.

[9] T. Kawashima, “Study on intelligent baby carriage with power assist system and comfortable basket,” *Journal of Mechanical Science and Technology*, Vol.23, pp. 974-979, 2009.

[10] T. Tanaka, Y. Satoh, S. Kaneko, Y. Suzuki, N. Sakamoto, S. Seki, “Smart suit: soft power suit with semi-active assist mechanism – prototype for supporting waist and knee joint,” *in Proc. of Int. Conf. on Control, Automation and Systems*, 2008, pp. 2002-2005.

[11] B. I. Oladapo, B. A. Vincent, A. S. Oluwole, M. T. Azeez, P. S. Asanta, Simulation Model to explore the Characteristic Pump Curve of an Injection Molding Machine: A case study of ABUAD water plant. International Journal of Engineering, Business and Enterprise Applications, 13(1), June-August, 2015, pp. 63-68.

[12] Z. Xinglong, C. Jian, Z. Jiping, *Development of Strategy and Current Situation of the Domestic Hydraulic Control Technology* [J], *Mechanical Science and Technology*, page: 10-12, 3rd issue, 1997.

[13] B. I. Oladapo , V. A. Balogun, A. O. M. Adeoye, C. O. Ijagbemi , Afolabi S. Oluwole, I. A. Daniyan , A. E. Aghor, A. P. Simeon. Model design and simulation of automatic sorting machine using proximity sensor, Eng. Sci. Tech., Int. J. 19 (2016) 1452–1456